The natural flood management manual

ciria

Flood and Coastal Erosion Risk Management R&D

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Part A provides an overview of natural flood management and a high-level checklist of the steps to deliver it

A Natural flood management and the manual

Image courtesy Victoria Coates

Courtesy River Restoration Centre

1 INTRODUCTION

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Chapter 01

Introduction

This chapter provides an overview of natural flood management and a high-level checklist of the steps to deliver it.

- *Summary drawings are provided of four NFM measures covered in detail in this manual:*
- *Runoff management: Chapter 7 provides more detail on this measure*
- *Runoff storage: Chapter 8 provides more detail on this measure*
- *Leaky barriers: Chapter 10 provides more detail on this measure*
- *Floodplain reconnection: Chapter 12 provides more detail on this measure*

1.1 WHAT IS NATURAL FLOOD MANAGEMENT?

NFM is used across the landscape to protect, restore or mimic the natural functions of catchments, floodplains, rivers and the coast. It is a potential approach to help reduce the risk of flooding from all sources such as rivers, the sea and surface water runoff. It should be considered alongside a range of other options to reduce both the likelihood of flooding (eg flood walls, embankments, storage reservoirs) and the impacts of flooding (eg improved flood warning and recovery).

The starting point for any NFM work is a desire to reduce flood risk, and a recognition that NFM may be a viable option to do this, by working with natural processes across the landscape. NFM can perform one or more primary functions relating to flood risk management:

- increase infiltration
- slow the flow of water
- store water
- hold back sediment.

It can also perform secondary functions to provide co-benefits, such as habitat creation and biodiversity enhancement, soil improvement and retention, water quality improvement and carbon storage, and can create more valuable landscapes leading to recreation or tourism opportunities for the local and wider community. Equally, other initiatives, which have their primary objectives outside of flood risk management, can also provide a secondary flood risk co-benefit (eg biodiversity-driven projects can help reduce flood risk).

NFM can take many different forms and can be applied at different scales, in urban and rural areas, by altering the way habitats, land, rivers, estuaries and the coast, are managed (**Figure 1.1**).

1.2 RIVER AND CATCHMENT-BASED NFM MEASURES

NFM, to reduce the risk of surface water and river flooding, can be applied in different ways. The NFM measures included in this manual are detailed in **Table 1.1** and those given more focus are shown in bold.

There is considerable overlap between some measures. This is because some can be used in different ways in different places in the landscape. For example, leaky barriers can be used to both manage overland runoff and stream or river flows, and bunds can be used to intercept flow pathways and store runoff. It is also important to consider a range of measures in a range of locations to reduce the risk of relying on a single solution or a particular location.

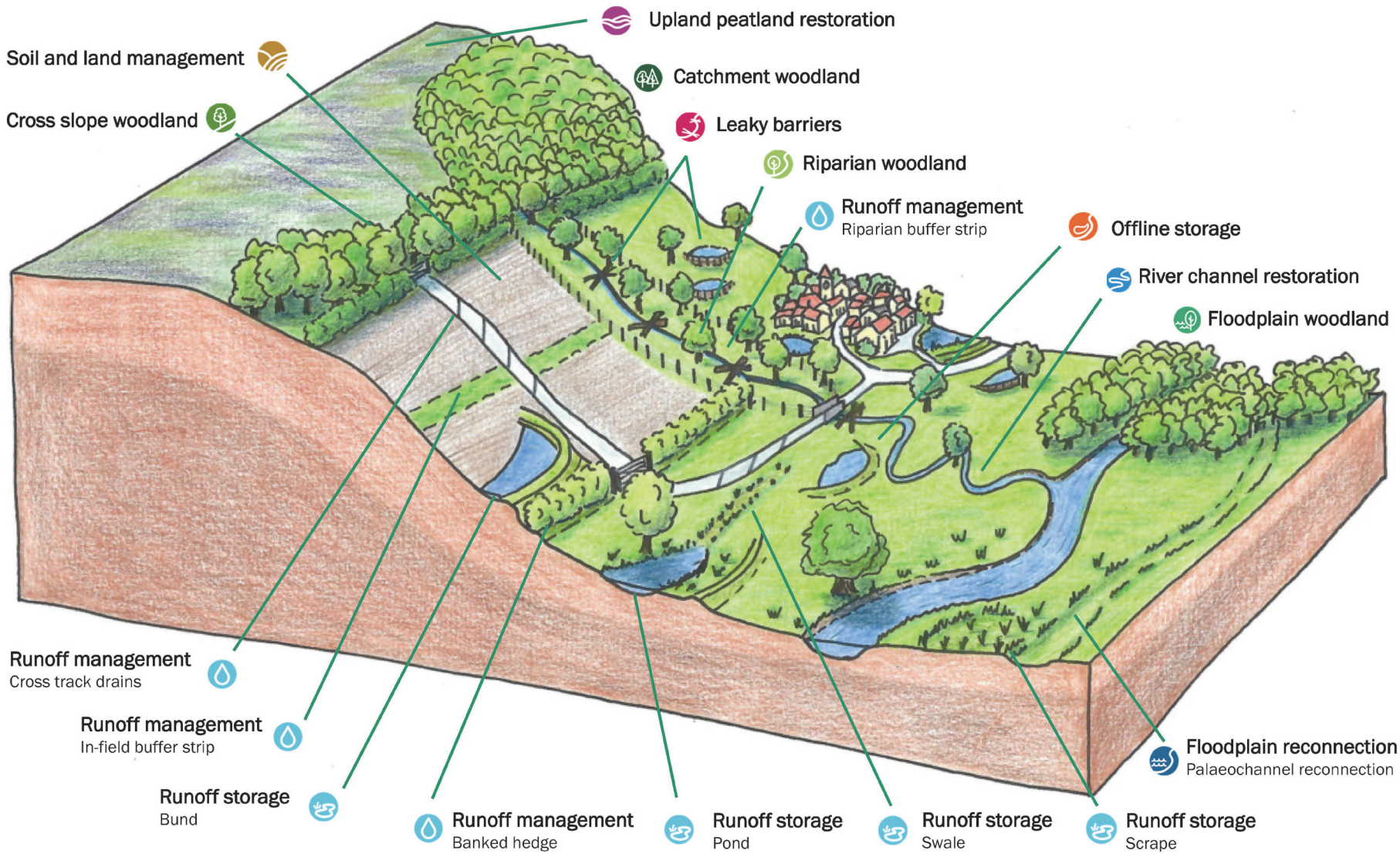


Figure 1.1 NFM across a river catchment

TABLE 1.1 Types of NFM in a river catchment

Measure	Measure types	How it works	Consider alongside
Upland peatland management 	Revegetation and habitat management Gully blocking using leaky barriers for peatlands Ditch blocking Hillslope pool creation	Manage upland peatland and enhance ability to store and slow the flow of water from headwaters. Revegetate and roughen bare areas and encourage dense peat-forming vegetation. Block artificial drainage channels (grips) to support vegetation change. Stabilise eroded gullies. Install leaky barriers that are appropriate for peatland to provide enhanced flood storage. Create pools to buffer the rainfall response.	Upland peatland management typically takes place in the headwaters of a catchment and so can be adopted upstream of all other NFM measures. They need to be designed to suit the upland peatland environment.
Soil and land management 	Changes to farm management practices Reduce soil compaction Encourage more natural habitats	Restore or enhance the ability of soil to infiltrate and store water.	Runoff management Runoff storage Woodland (all types)
Runoff management 	Cross track drains and diverters Cross slope hedgerows (including banked hedges) Buffer strips	Interrupt or divert overland flow pathways across the landscape, encourage infiltration into the ground, slow the flow and divert water away from problematic locations.	Soil and land management Leaky barriers across overland flow pathways Cross slope or catchment woodland Riparian or floodplain woodland in riparian buffer strips Runoff storage to store diverted water
Runoff storage 	Ponds Scrapes Bunds Swales	Store water on overland flow pathways to reduce the flow towards a watercourse and encourage infiltration.	Soil and land management Runoff management Cross slope or catchment woodland Leaky barriers across overland flow pathways Offline storage adjacent to runoff pathways
Cross slope woodland 		Plant woodland belts across slopes to slow the flow down slopes, intercept rainfall, increase evaporation and uptake by vegetation and infiltration.	Runoff management and storage Soil and land management
Riparian woodland 		Plant trees in the river corridor to slow the flow in channels, intercept rainfall, increase evaporation and uptake by vegetation and infiltration.	River channel restoration and floodplain reconnection Leaky barriers on watercourses Buffer strips along watercourse Floodplain woodland

continued...

TABLE 1.1 Types of NFM in a river catchment (contd)

Measure	Measure types	How it works	Consider alongside
Floodplain woodland 		Plant trees in the floodplain to slow the flow across it. Intercept rainfall, increase evaporation and uptake by vegetation and infiltration.	River channel restoration and floodplain reconnection Leaky barriers on watercourses Riparian woodland Soil and land management Buffer strips along watercourses Offline storage in/adjacent to floodplains
Catchment woodland 		Increase woodland cover across the landscape to intercept rainfall, increase evaporation and uptake by vegetation and infiltration.	Soil and land management Runoff management and storage Other woodland measures Leaky barriers and offline storage on runoff pathways and watercourses within woodland
Leaky barriers 	Leaky barriers on watercourses Leaky barriers on runoff pathways	A flow obstacle to slow down and store water in small streams and their immediate floodplain. Or a barrier across overland flow pathways to store and slow water.	Riparian or floodplain woodland to supply woody material in the future Soil and land management Runoff management and storage eg buffer strips along watercourse River channel restoration and floodplain reconnection Catchment, floodplain and riparian woodland
Offline storage 	Next to watercourses Adjacent to runoff pathways	Divert water from an overland flow pathway or stream to be temporarily stored nearby.	Leaky barriers to divert water into storage areas Runoff management to divert water from flow pathways Runoff storage Could locate within floodplain or catchment woodland
Floodplain reconnection 	Lower, remove or set back existing embankments Reconnect palaeochannels In-channel features to push flow into floodplain Floodplain wetland restoration	Restore or enhance the natural function of the floodplain to store water.	River channel restoration Floodplain and riparian woodland Leaky barriers to push flow into floodplain Offline storage
River channel restoration 	Restore channel planform Restore longitudinal connectivity Restore lateral river movement	Restore modified river channels due to artificial changes (direct or indirect).	Floodplain reconnection Floodplain and riparian woodland Leaky barriers Buffer strips along watercourse

Figure 1.2 Example NFM measures

1.3 WORKING WITH NATURE

The philosophy of NFM centres on working with nature where possible to reduce flood risk close to the origin of flooding. **Figure 1.3** explains this approach, showing that the focus should be to work with nature to protect, then restore and mimic hydrological processes.

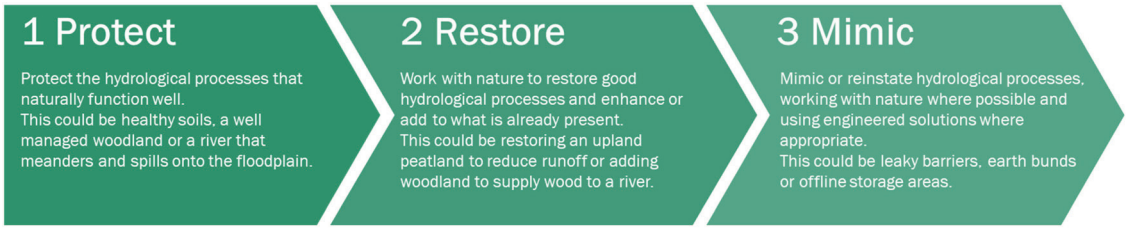


Figure 1.3 The NFM continuum of protect, restore and mimic hydrological processes

An NFM project should seek to retain features in the landscape that are naturally functioning well. It should then seek to restore natural hydrological processes across the landscape, by enhancing or adding to what is present across the catchment. Finally, if the entire landscape cannot be restored, an NFM approach can be adopted to mimic hydrological processes or to give greater flood risk benefit. This could mean adding more engineered storage features to the landscape rather than, or as well as, working at source to improve the ability of soil to store water. Alongside this hierarchy there are five key principles to adopt when working with nature (**Figure 1.4**).

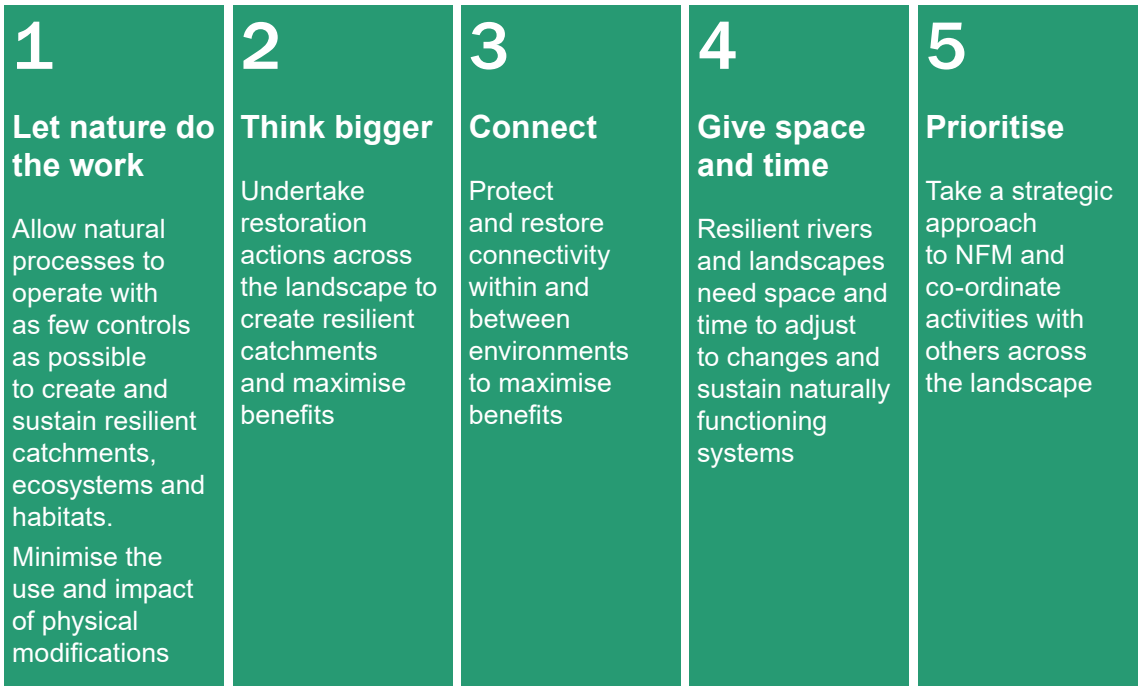


Figure 1.4 Five key principles for working with nature

1.4 HOW TO USE THE MANUAL

This manual is divided into four parts (**A to D**) plus appendices and is colour coded based on those sections (**Figure 1.5**). It starts with a high-level overview and progresses into more detailed information.

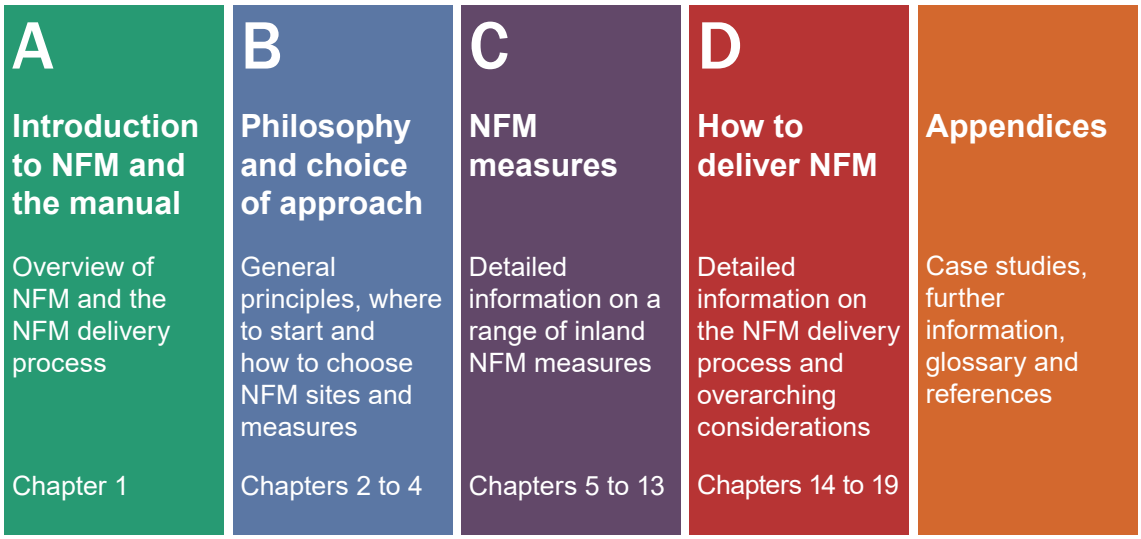


Figure 1.5 Structure of this manual

1.5 THE NFM DELIVERY PROCESS

The delivery process is the starting point in this manual to appreciate the process to implement NFM. There are five key steps to the process, shown in **Figure 1.6**. It is important to work with other interested groups to maximise the outcomes of NFM at every stage.

The delivery of NFM combines methods used in flood risk management (eg assessment of risk and hydrological modelling) and environmental management (eg understanding natural processes and ecological impacts).

NFM is most effective when delivered as a long-term, circular process. This enables increased understanding to improve design and delivery as the project progresses. This will result in more informed decisions over time and the increased likelihood of a successful project. The level of detail needed at any given step is highly project specific and should be proportionate to the overall intended outcome. It is also important to recognise that there may be several full or part iterations around the delivery process – NFM projects tend to be more organic in their nature than engineering projects – NFM measures can be incrementally added over time as more partners become involved and support for this way of working builds momentum in a place.

The following sections explain the key steps in the delivery process and provides high-level checklists to ensure that all aspects are considered. **Figure 1.7** signposts where more information is found in later sections of this manual.

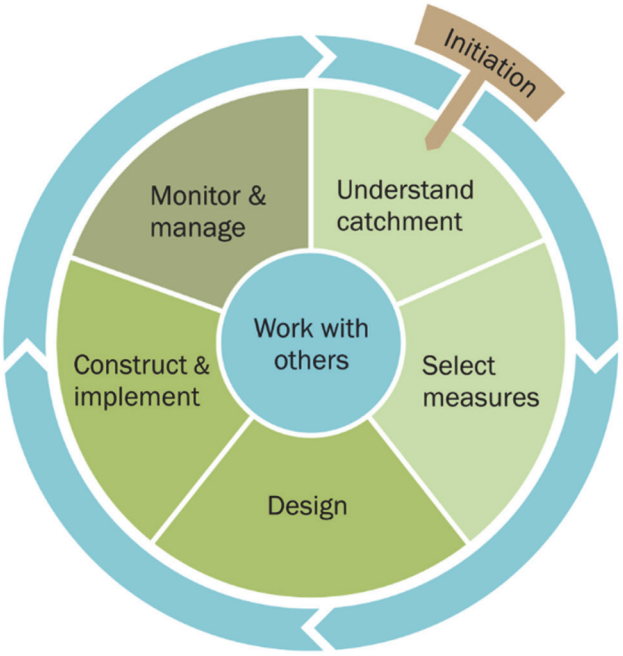


Figure 1.6 The NFM delivery process

Progress through a project

Delivery stage	What is needed?	Key information	Further detail
Initiation	Understand the NFM delivery process, agree project aims, raise support and understand wider aspirations	1 Introduction 2 Aims and success factors 3 Top tips for successful NFM	
Understand catchment	Gather information to understand issues and opportunities in the catchment	4 Select sites and measures	
Select measures	Select sites and measures to target the catchment issues and maximise outcomes	4 Select sites and measures Part C NFM measures	14 Hydrology and hydraulics 15 Costs and benefits 16 Environmental considerations
Design	Develop appropriate NFM designs	Part C NFM measures	17 Design and materials
Construct and implement	Deliver the NFM	Part C NFM measures	18 Construction and implementation
Monitor and manage	Aftercare for the NFM delivered	Part C NFM measures	19 Monitor and manage
Work with others	Integral to maximise outcomes and co-benefits	3 Top tips for successful NFM	

Figure 1.7 How to use the manual to deliver an NFM project

1.5.1 Understand the catchment

To start, an NFM project requires a broad understanding of the catchment and the interests of the people within it. This understanding is an iterative process and, due to the complex and dynamic nature of river systems, it is never complete.

There can be a number of starting points dependent on the nature of a catchment and the people involved. Projects range from small-scale interventions to multi-catchment strategies, and can be initiated and led by a variety of organisations, stakeholders and partnerships.

The success of NFM projects rests on early engagement, to gather support from the community and landowners as well as flood risk authorities. Support from these stakeholders will provide a platform to deliver NFM and inspire confidence in the project.

Understanding the catchment is critical to understand the source of catchment impacts and the factors contributing to these issues and also identify opportunities to address these. This understanding means that NFM measures can be targeted to both reduce flood risk and deliver co-benefits.

Checklist	✓
Understand flood risk (where and what floods; sources, pathways and receptors)	
Understand the interests, aims and aspirations of everyone involved in the catchment	
Find others to work with to achieve more together	
Define the project aims and success factors; review them as understanding increases	
Identify potential funding sources	
Understand the physical nature of the catchment and catchment pressures	
Understand current and future strategies, plans or developments	
Identify opportunities to reduce flood risk, address impacts and maximise co-benefits	
Understand risks and barriers to implementation (eg land ownership, infrastructure)	
Put in place any monitoring needed to gather missing data or understand project success	

1.5.2 Select measures

Select NFM sites and measures that will achieve the project objectives and address the causes of flood risk in a catchment. The NFM measures chosen should aim to address the issues identified during the ‘understand the catchment’ step and maximise opportunities for co-benefits.

Checklist	✓
Identify priorities for NFM locations and measures	
Protect and restore what is there before seeking add more engineered measures	
Combine a range of NFM measures and types	
Seek to address flood risk issues at source and align to the catchment hydrology and hydraulics	
Take opportunities to address wider catchment issues and deliver co-benefits	
Select measures to align with project aims – funding requirements, landowner or community preference, and the people involved and expertise available	
Select measures to maximise environmental benefits and minimise detrimental impacts	
Consider how measure choice will affect the overall costs and benefits	
Understand if specific consents or permissions may be needed	
Consider if design, construction and future management requirements affect the choice (eg expertise available, health and safety, land access)	

1.5.3 Design

Design is a vital part of the process as it is required to obtain permission to construct or implement NFM measures. The main benefits of a good design are:

- it enables NFM principles to be embedded
- good project performance
- reduction of risk
- positive communication and engagement
- allows the monitoring of project success.

The level of detail required in design depends on the type, scale and location of the NFM measure. The optimal design of an NFM measure depends on the unique conditions of the site and the aims of the project. Safety needs to be considered in design (see **Section 17.5**) to reduce health and safety risks during construction and throughout the lifespan of measures.

Checklist	✓
Work with the community to improve designs or overcome implementation barriers	
Specify the NFM measures to be constructed	
Align the level of design to the NFM measure, scale and location and the performance aims	
Optimise the hydrological and hydraulic design of individual measures	
Refine understanding of the costs and benefits of the project	
Maximise environmental opportunities and minimise harmful environmental effects	
Understand and eliminate or reduce safety risks	
Consult with the relevant consenting authorities to understand if the design meets their needs	

1.5.4 Construct and implement

The approach to construction and implementation is dependent on the type of measure and the outputs of the design process.

The aspects to be considered are unique to a site and include the timing of works, safety, liability, access, environmental designations and more.

Some measures can be implemented in a day with a group of volunteers, while others require a civil engineering approach, which can take longer.

Checklist	✓
Make the most of collective working to construct NFM measures effectively	
Plan how to construct or implement the measures as they are specified in the design	
Ensure that health and safety risks are considered and minimised	
Confirm site access and understand any constraints (eg services, timing)	
Plan how to minimise and manage any harmful environmental impacts	
Ensure all necessary consents and permissions are in place	
Keep appropriate records of the completed measures and their future management	

1.5.5 Monitor and manage

The specific approach to monitoring will depend on the aims and objectives of the project. Successful monitoring should:

- establish the strengths and weaknesses of both the individual measures and the wider NFM project
- target the key indicators of success, at the scale at which they are expected to change
- inform the catchment understanding, measure selection, design and construction to improve the current and subsequent projects.

By working with natural processes, NFM measures may require little or no ongoing management. In some cases, NFM measures require maintenance (periodic or based on flood events, eg woodland management, repairs) or adaptive management (changes and alterations). This is informed by monitoring and inspection findings.

Checklist	✓
Develop and implement a site management plan	
Assign responsibility for inspection and management or maintenance	
Monitor the overall flood risk benefits and co-benefits to demonstrate project success	
Monitor whether individual measures are working as planned	
Consider mechanisms to incorporate adaptive management (changes and alterations)	

1.6 AIM AND SCOPE OF THE MANUAL

The manual covers the delivery of NFM from start to finish: problem identification, conception, funding, design, construction, inspection, maintenance, adaptive management and end-of-life considerations. It is primarily concerned with the 'where' and 'how' of NFM delivery, rather than 'why', and aims to provide confidence in NFM and ensure the best outcomes are delivered. The manual is not intended to be exhaustive and innovation in this area is constantly emerging.

It is intended for use in the UK and is tailored to the geographical settings and conditions of the country. It does not cover the legal context for countries outside the UK although it draws on advice and case studies from elsewhere and could be of assistance for overseas projects.

The manual covers NFM measures to reduce the risk of flooding from surface water and rivers. It does not include coastal NFM to reduce the risk of tidal or coastal flooding by techniques including restoration or creation of salt marshes, mudflats, dunes and beaches. Further guidance on coastal NFM is given in Forbes *et al* (2015) and Burgess-Gamble *et al* (2018).

Detailed technical advice is given on four measures (shown in bold in **Table 1.1**). These are considered more challenging to deliver and with less detailed information available. The remaining measures are each given a one-page summary with signposts to other publications. The manual is structured so that more information can be added on the other measures.

The primary audience is those implementing NFM in their local river catchment. This may be individual or groups of landowners or managers, a community group or an environmental non-governmental organisation (NGO), such as a Rivers Trust or Wildlife Trust. It may also be used by the full range of authorities, organisations and professionals working on NFM projects (**Section A3.2**). It is aimed at groups implementing projects to reduce flood risk, although it can also be used to help design other nature-based solutions that may provide flood risk benefits alongside other aspirations.

BOX 1.1 Definitions of NFM and similar approaches

Name	Definition
NFM	An approach to reduce flood risk by working with natural processes across the landscape.
Nature-based solutions (NbS)	An approach that adopts natural processes to overcome or offset environmental issues. NFM is a type of NbS, focusing on flood risk, and achieving co-benefits. Other nature-based solutions may focus on different outcomes, for example biodiversity improvements, water quality improvements or climate resilience, and could also provide a flood risk benefit. Similar techniques may be used to achieve these outcomes.
Natural water retention measures	Term used across Europe with a similar meaning to NFM. Natural water retention measures aim to retain and enhance the natural water storage capabilities of the landscape, soil and aquifers using natural processes.
Sustainable drainage systems (SuDS)	Ways to manage surface water runoff (the flow of rainwater across the surface) by capturing, using, absorbing, storing and transporting rainfall in a way that mimics nature. They also reduce pollutants as well as provide other amenity and biodiversity benefits. Some overlap with NFM. Described in detail in Woods Ballard *et al* (2015).
Blue-green infrastructure	Uses the landscape and NbS to provide multi-functional spaces that are strategically planned and managed. The green refers to elements such as parks, gardens, playing fields trees and woods; the blue refers to watercourses, canals, ponds, lakes and wetlands.

TABLE 1.2 Key introductory references to NFM

Common name	Description	Reference
Natural mitigation of flood risk	A short summary of evidence for the effectiveness of NFM and successful governance approaches to implementation	UK Parliament POST (2020)
SEPA NFM handbook	A guide for Scotland, giving a good overview to NFM techniques	Forbes *et al* (2015)
WWNP Evidence base	A guide for England and Wales, brings NFM research and evidence together	Burgess-Gamble *et al* (2018)
NFM – A farmer's guide	Aimed at landowners and farmers. Focuses on benefits to the farm	SRUC (2019)
FWAG information sheets	Information sheets for landowners on a range of measures	FWAG South West: **https://www.fwagsw.org.uk/natural-flood-management-information-sheets**

Further reading

UK Parliament POST (2020) *Natural mitigation of flood risk*, Postnote number 623, Parliamentary Office of Science and Technology, London, UK

⇨ A short summary of evidence for the effectiveness of NFM and successful governance approaches to implementation

https://researchbriefings.files.parliament.uk/documents/POST-PN-0623/POST-PN-0623.pdf

Forbes, H, Ball, K and McLay, F (2015) *Natural flood management handbook*, Scottish Environment Protection Agency, Stirling, Scotland (ISBN: 978-0-85759-024-4)

⇨ A guide for Scotland, giving a good overview to NFM techniques

https://www.sepa.org.uk/media/163560/sepa-natural-flood-management-handbook1.pdf

Burgess-Gamble, L, Ngai, R, Wilkinson, M, Nisbet, T, Pontee, N, Harvey, R, Kipling, K, Addy, S, Rose, S, Maslen, S, Jay, H, Nicholson, A, Page, T, Jonczyk, J and Quinn, P (2018) *Working with natural processes – the evidence directory*, SC150005, Environment Agency, Bristol, UK

⇨ A guide for England and Wales, brings NFM research and evidence together

https://assets.publishing.service.gov.uk/media/6036c5468fa8f5480a5386e9/Working_with_natural_processes_evidence_directory.pdf

SRUC (2019) *Natural flood management – a farmer's guide*, SAC Consulting and the Tweed Forum, Scotland

⇨ Aimed at landowners and farmers. Focuses on benefits to the farm

https://www.farmingandwaterscotland.org/downloads/natural-flood-management-a-farmers-guide/

FWAG South West *FWAG information sheets*

⇨ Information sheets for landowners on a range of measures

https://www.fwagsw.org.uk/natural-flood-management-information-sheets

Floodplain reconnection

Chapter 12 provides more detail

What is floodplain reconnection?

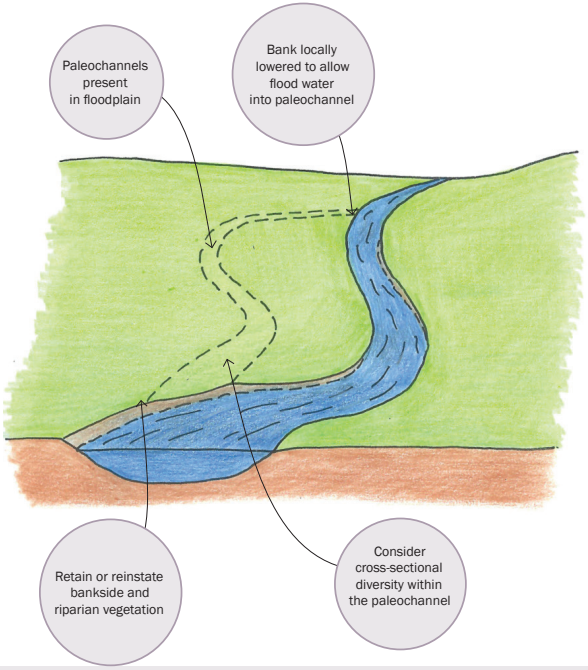
- 'Reactivation' of floodplains to reverse previously reduced connection between the river and its floodplain
- Increases the frequency and/or spatial extent of floodplain inundation
- Allows water to be stored outside the main channel in times of flood
- Deliver adjacent to the river channel, usually in the middle to lower reaches of a river catchment

Key metrics

- ££ Moderate to high cost
- Moderate build complexity
- Low maintenance requirements
- Indefinite design life

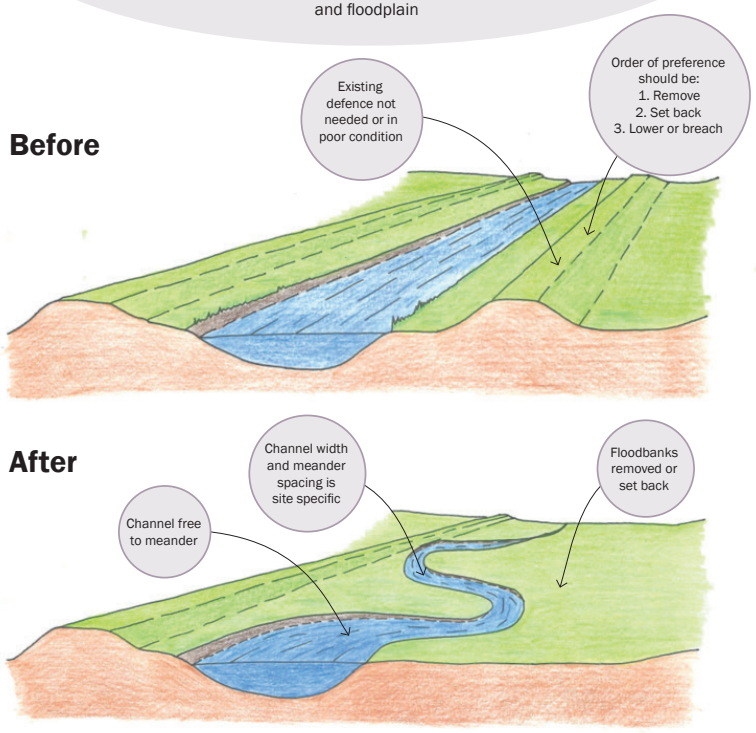
Paleochannel reconnection

Allows former river channels (in the floodplain) to become inundated in times of higher flows/flood



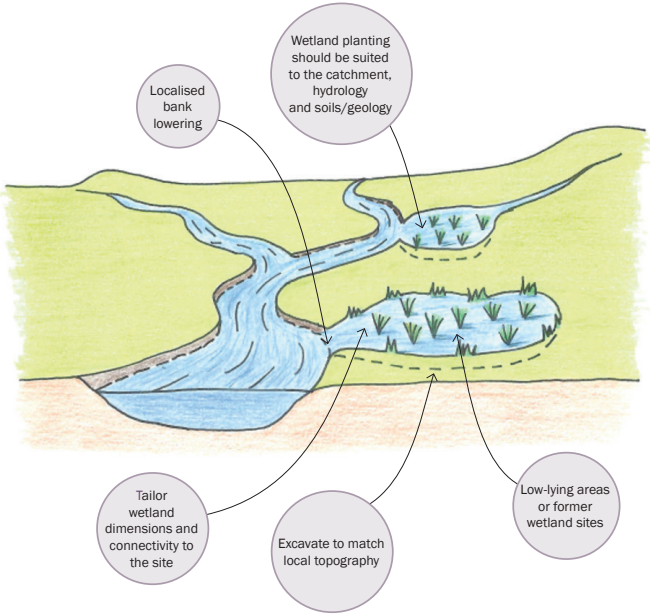
Remove, set back or lower flood banks

Allows the physical transfer of water between a river and floodplain



Floodplain wetland restoration

Create or restore wetland areas within the floodplain



Key benefits:

- **Flood risk reduction:** reduction in flood risk elsewhere by directing flow onto the floodplain
- **Restored natural geomorphological processes and ecosystem services:** transfer of water, sediment and organic matter from channel to floodplain creates more room for the river
- **Drought resilience:** slow release of stored water from the floodplain
- **Climate regulation:** increased resilience by making space for flood waters. Carbon capture and storage by wetlands

Work well with:

- **Riparian or floodplain woodland** to further slow the river flow
- **Leaky barriers** to elevate water into a reconnected floodplain or wetland
- **River channel restoration** alongside floodplain reconnection
- **Offline storage** incorporated into the same location
- **Riparian buffer strips** to maximise the impact in a river corridor

Design notes common to all floodplain reconnection measures:

- The size of the measure is site specific and hydraulic modelling may be needed to design it
- Impacts on flood risk, erosion and deposition, and environmental receptors need to be considered
- Excavation may be needed – the amount is site and design specific
- Minimise loss of mature trees
- Consents may be required for these measures. Refer to the manual for further detail

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Leaky barriers

Chapter 10 provides more detail

What are leaky barriers?

- They obstruct flows within watercourses or along runoff pathways
- They raise the water level, slow the flow and increase channel roughness, which spreads out water over a wider area and reconnects the channel and floodplain
- Most effective when several leaky barriers are built in series along the same flow path or watercourse
- Constructed using live materials, wood or stone

Key metrics

- Low cost
- Easy to build
- Low maintenance requirements
- 5–10 years design life

Woodland watercourse

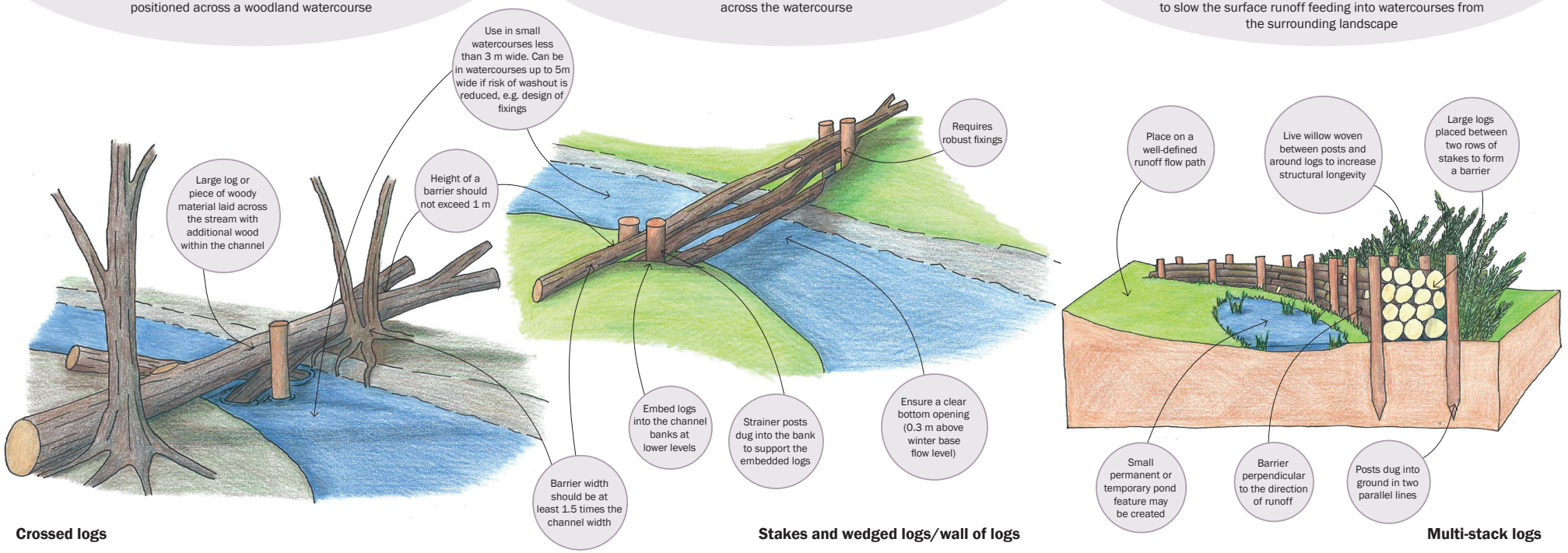
Live materials or wood sourced from site that is hinged or positioned across a woodland watercourse

Non-woodland watercourse

Non-living, but preferably locally sourced wood positioned across the watercourse

Runoff pathway

Constructed perpendicular to surface water runoff pathways to slow the surface runoff feeding into watercourses from the surrounding landscape



Crossed logs | **Stakes and wedged logs/wall of logs** | **Multi-stack logs**

Key benefits:

- **Flood risk reduction:** leaky barriers slow in channel flows and direct flow onto the floodplain. This helps to store water, increase infiltration, increase root uptake and evaporation and reduce flood flows downstream
- **Environmental improvement:** leaky barriers can improve sediment dynamics and flow diversity and also stabilise the riverbank and floodplain
- **Habitat creation:** leaky barriers can provide food sources, shelter and perches for wildlife. They can trap floating debris and sediment, to help regenerate habitat
- **Drought resilience:** leaky barriers on runoff pathways can retain water during dry periods and increase soil moisture

Work well with:

Woodland to provide a source of material. This can be used to restrain leaky barriers and help promote the natural formation of barriers on watercourses over time

Leaky barriers can be used to raise water out of the channel to enable **floodplain reconnection** and the diversion of flow into **offline storage** areas

Riparian buffer strips can exclude stock from accessing leaky barriers and also improve the surrounding riparian habitat

Leaky barriers positioned on runoff pathways interrupt flows and can act as a **runoff storage** feature

Design notes common to all types of leaky barrier:

- Heavy lifting or machinery may be needed to position logs and drive in stakes
- Design and locate to take advantage of local materials
- Locate so that floodwater remains within the landowner boundary or obtain agreement from the neighbouring landowners
- Ideally build several structures in series along the sameflow path or watercourse. The most downslope structure should be most robust to catch debris if upslope structures were to fail
- Consents may be required for these measures. Refer to the manual for further detail
- Do not locate in the area of water ponded upstream of another barrier
- Minimise use of artificial materials

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Runoff management

Chapter 7 provides more detail

What is runoff management?

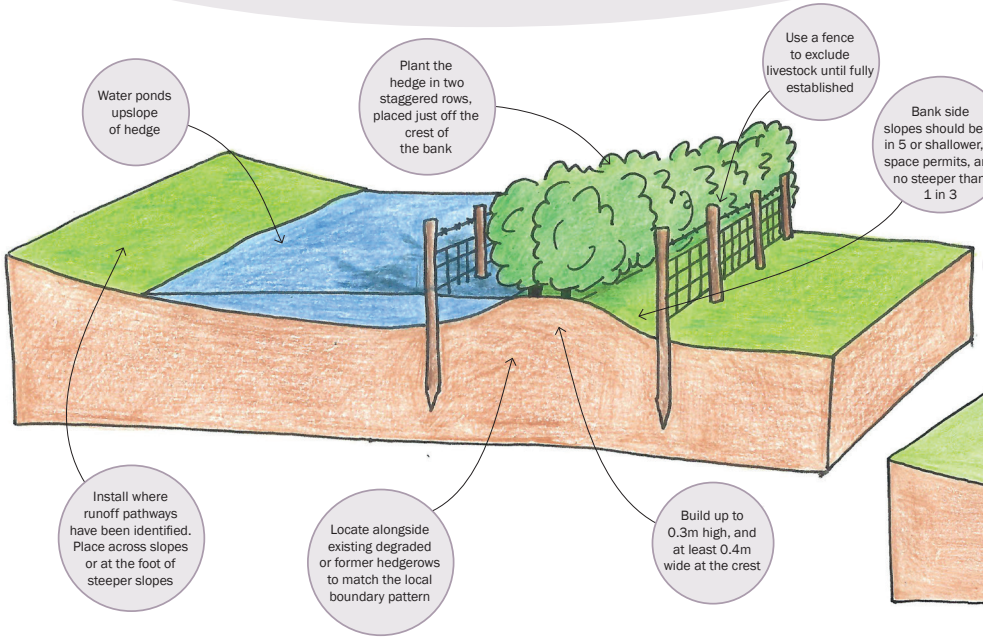
- Aims to interrupt, slow or divert overland flow pathways across the landscape
- Encourages infiltration into the ground and diverts water away from challenging locations
- Includes cross drains and deflectors; cross slope hedges and buffer strips

Key metrics

- Low cost
- Easy to build
- Moderate maintenance requirements
- Indefinite design life if maintained

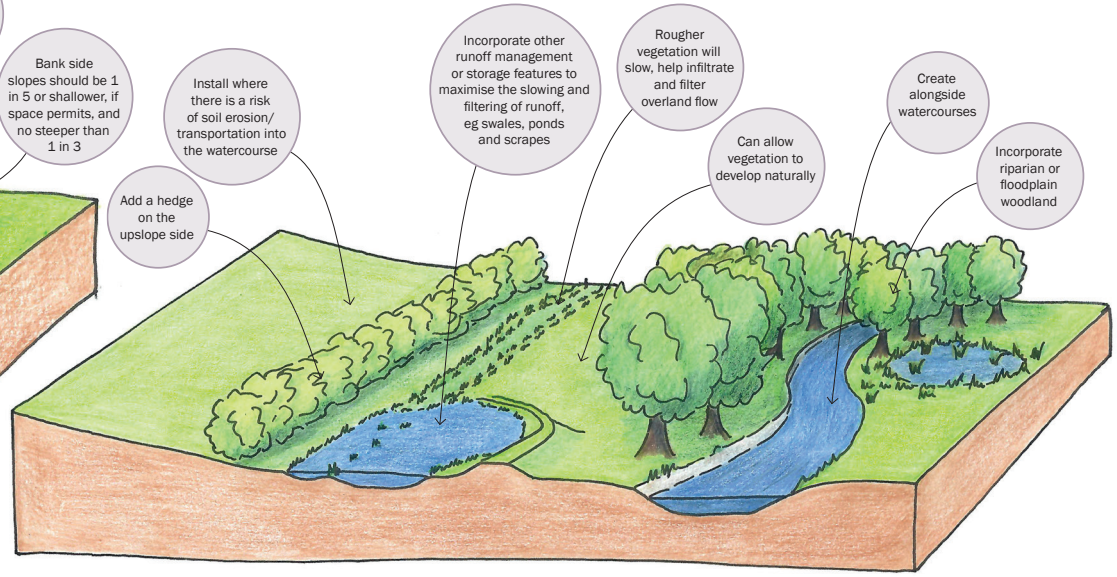
Banked hedge

Hedges planted cross slope on a raised bed or bank, to intercept flow pathways and store water, to increase infiltration and transpiration



Enhanced riparian buffer strip

Linear features strategically placed across a slope alongside a watercourse to allow the establishment of rougher vegetation to slow, and help infiltrate and filter overland flow



Key benefits:

- **Flood risk reduction:** measures divert, infiltrate and store runoff, to reduce downstream flood risk and divert water away from challenging areas such as highways and infrastructure
- **Water quality:** measures can be designed to trap and filter contaminated runoff
- **Climate regulation:** hedgerows and buffer strips can capture and store carbon
- **Habitat creation:** hedgerows and buffer strips create habitat which can be used as wildlife corridors to link existing habitats
- **Soil health:** help retain soil on the land rather than it being washed into watercourses
- **Farm operation:** hedgerows can be a long-term field boundary and are beneficial to livestock health

Work well with:

- **Soil and land management** to reduce runoff and soil loss at source
- **Runoff storage** to store water alongside measures to slow runoff
- **Woodland** across the landscape to reduce the rate of runoff
- **Leaky barriers** to slow the flows in watercourses or on runoff pathways
- **River channel restoration and floodplain reconnection** to provide further benefit in the river corridor

Design notes common to all runoff management measures:

- The appropriate runoff management measure is dependant on location, purpose and construction method
- Living and natural materials should be used where possible
- Consider access requirements for maintenance and livestock access for grazing or water needs
- Bunds, swales, ponds or scrapes require earthworks. Bunds need compaction in layers
- Protect new trees from pests for the first two years
- Consider adding hedgerow trees to increase biodiversity, variation and structure
- Plant hedges or trees between October and March
- Use native trees similar to species present in the local landscape
- Connect existing habitats and/or create wildlife corridors
- Avoid sites where invasive species are a known issue
- Consents may be required for these measures. Refer to the manual for further detail

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Runoff storage

Chapter 8 provides more detail

What is runoff storage?

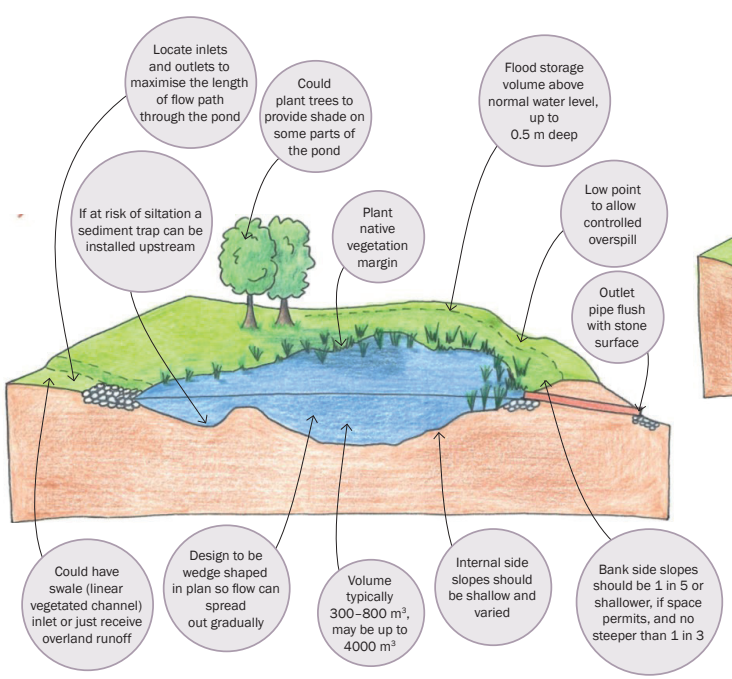
- Measures that temporarily store water
- They fill during rainfall events and empty slowly
- Increase water storage across a catchment which reduces flood risk downstream
- Best in locations with sloping topography where runoff flows in defined pathways
- Include ponds, scrapes, swales and bunds

Key metrics

- ££ Moderate cost
- Moderate build complexity
- Moderate maintenance requirements
- Indefinite design life if maintained

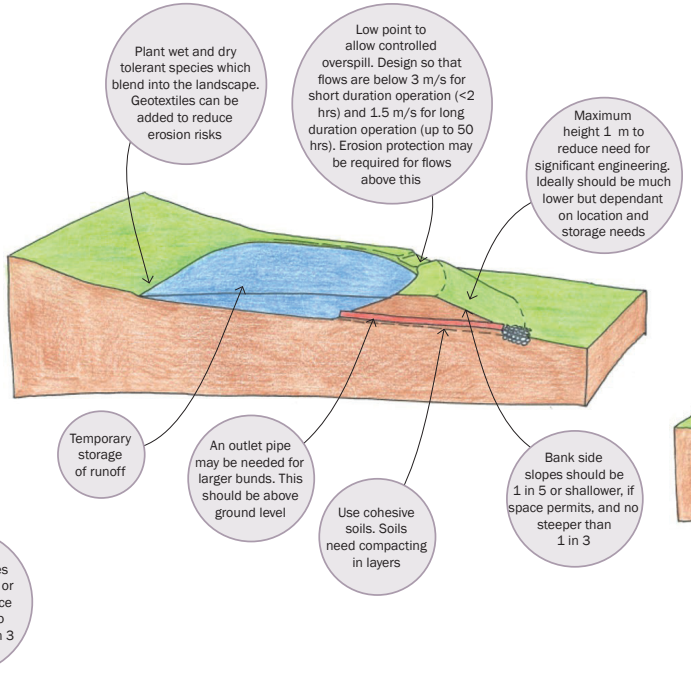
Pond

Depression that holds water permanently with additional capacity for storm events



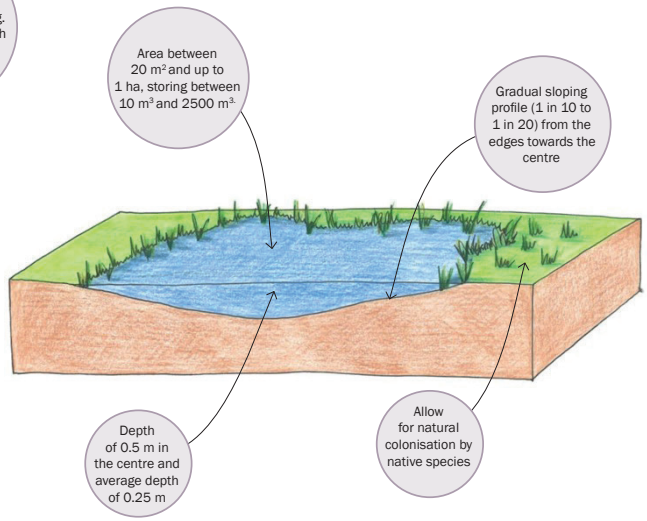
Earth bund

A bank created to provide flood storage or to help divert runoff



Scrape

Depressions that fill with water in the winter and gradually dry out in the spring and summer



Key benefits:

- **Flood risk reduction:** measures are effective as soon as they are installed. Runoff rates are reduced by water retention and controlled flow release which slows the rate of rise of a flood peak. Water storage increases the opportunity for infiltration and evaporation
- **Water quality:** measures allow sediment to settle out from the flow. This has a positive impact on water quality and improves the functioning of downstream watercourses
- **Habitat creation:** these measures, particularly ponds and scrapes, provide new wildlife habitats and increase biodiversity
- **Climate regulation:** wetland habitats, like ponds and scrapes, capture and store carbon
- **Soil retention:** storing runoff close to source allows soil to be trapped in storage features, rather than entering watercourses. Soil can then be returned back to farmland

Work well with:

- **Soil and land management** to reduce runoff at source across the landscape
- **Runoff management or cross slope woodland** alongside measures to interrupt, slow or divert runoff and to store it
- **Catchment woodland** to reduce runoff at source
- **Leaky barriers** to slow and store water on runoff pathways
- **Offline storage** to hold water adjacent to runoff pathways and to slow the flow

Design notes common to all runoff storage measures:

- Avoid volumes over 10000 m³ as can lead to additional duties under reservoir safety legislation
- Design to release water so that storage can be used again in the next storm
- Likely to require earthworks
- Ponds and earth bunds may require an outlet to provide additional capacity during storm events. Outlets may need a headwall to support earhworks above and prevent material falling down into the flow. Erosion protection may be needed
- Size of the measure based on its catchment area and target rainfall event
- Consents may be required for these measures. Refer to the manual for further detail

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